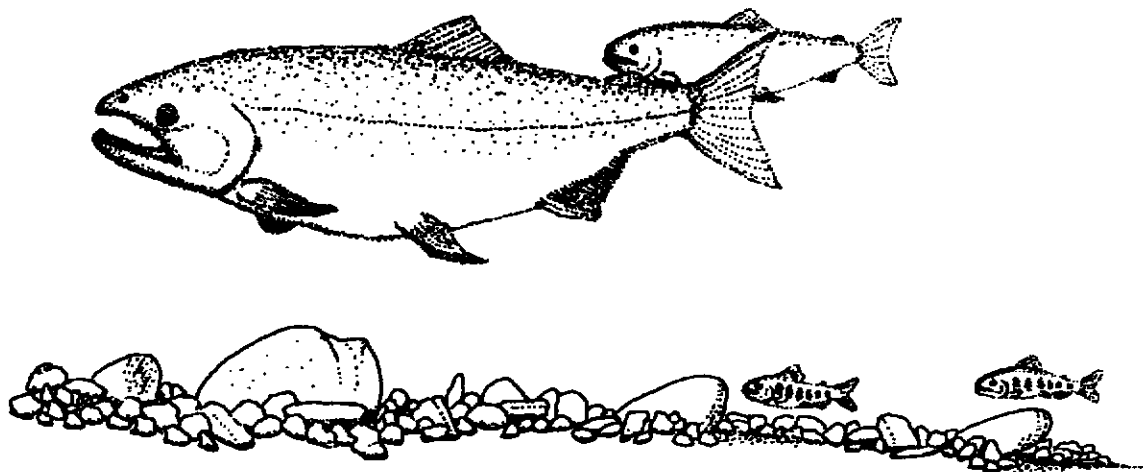**U.S. FISH AND WILDLIFE SERVICE**

PRELIMINARY RESULTS OF WOODY DEBRIS USE

BY SUMMER REARING JUVENILE COHO SALMON

IN THE CLEARWATER RIVER, WASHINGTON

WESTERN WASHINGTON FISHERY RESOURCE OFFICE

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Preliminary Results of Woody Debris Use by Summer Rearing Juvenile Coho Salmon (*Oncorhynchus kisutch*) in the Clearwater River, Washington

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Abstract

Preliminary results of a 3-year study evaluating the use of small woody debris bundles (evergreen trees) as habitat enhancement structures for juvenile coho salmon (*Oncorhynchus kisutch*) in the main stem Clearwater River (average discharge = 1,376 cfs) is presented. The effectiveness of these structures in attracting and sustaining juvenile coho salmon during the summer and providing immigrants into wall-base channels during the fall was compared to that of naturally occurring debris and to areas with no woody debris (controls). The physical environment surrounding these debris structures was measured to determine the variables most important to summer rearing juvenile coho salmon.

Similar numbers of juvenile coho salmon were observed at introduced and natural debris accumulations, while no coho were observed in pools lacking woody debris. When each environmental variable was tested for its influence on coho abundance, significantly more coho occurred in the most dense debris. Significantly more coho also were observed in larger debris areas. No other single environmental variable significantly influenced coho abundance around debris structures.

Significant multiple regression variables for introduced debris included surface area, debris density, current velocity in the center of the debris accumulation, and depth on the outer (mid-stream) edge of the debris. In contrast, significant multiple regression variables for natural debris accumulations included surface area, debris density, riverine habitat type, (pool, riffle, glide) and an interaction term between surface area and riverine habitat type. The positive influence of debris surface area on coho abundance was greater in pools and riffles than in glides.

In order to determine the contribution of juvenile coho salmon from introduced and naturally occurring debris to wall-base channel immigration, juvenile coho salmon captured at riverine debris structures were freeze-branded during summer low flow. Nine hundred and nine coho were branded from natural (229) and introduced (680) debris accumulations. Twenty-one marked coho from all debris structures were captured as they migrated into four monitored wall-base channels. Fourteen (14/229=6.11%) marked coho originated from natural debris structures, while 7 (7/680=1.03%) originated from introduced debris.

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Preliminary results suggest that introduced woody debris is at least as effective as natural debris stations in attracting and sustaining juvenile coho salmon during the summer. The most effective debris structures appear to be large, dense structures in pools. However, there is some indication that introduced structures provide fewer wall-base channel immigrants than naturally occurring debris. Preliminary results suggest that this technique could be used to increase the summer rearing capacity of the main stem Clearwater River.

Introduction

To increase coho salmon (*Oncorhynchus kisutch*) summer rearing habitat in the main stem Clearwater River, the Washington Cooperative Fish and Wildlife Research Unit (COOP), U.S. Fish and Wildlife Service (USFWS) and the Washington Department of Natural Resources (WDNR) have engaged in a habitat enhancement project. Woody debris bundles were placed in the main stem Clearwater River during spring, 1990. These structures, along with naturally occurring debris, were evaluated for use by juvenile coho salmon during summer, 1990. Results presented in this manuscript are from the first year of a 3-year study.

Woody debris serves many important functions in stream ecology. The formation of rearing pools and the provision of cover are often important functions for salmonid habitat (Bisson et al. 1987). Debris provides shelter from predators as well as areas of shade near stream margins, the preferred habitat of many juvenile salmonids (Hartman 1965; Chapman 1966; Allen 1969; Mundie 1969; Everest and Chapman 1972; Bisson et al. 1987). These areas often form the most productive fish habitat in large river channels (Bisson et al. 1987). Backwater pools or eddy pools associated with woody debris often concentrate food items (Bisson et al. 1987) and are the preferred habitats of juvenile coho salmon during the spring and summer (Nickelson et al. 1992a). This provision of foraging sites is important during the summer when most of the annual freshwater growth of salmonids occurs (Chapman 1965; Bisson et al. 1987).

Hall and Baker (1982) recommend that emphasis be placed on the rehabilitation of salmonid rearing areas, while Sedell and Luchessa (1982) state that emphasis should be placed on restoring habitat complexity to main stem channels of 4th to 7th-order streams. Woody debris has been used to enhance the rearing habitat and increase the carrying capacity of streams since the 1930's (Tarzwell 1936). However, enhancement research in the Pacific Northwest is relatively young, occurring only since the early 1970's (Bisson et al. 1987). The summer carrying capacity of salmon and trout in Oregon streams (Anderson 1982; House and Boehne 1985, 1986; Bisson et al. 1987; Nickelson et al. 1992b) and British Columbia (Ward and Slaney 1979; Bisson et al. 1987) has been increased with the addition of debris. Common techniques of enhancement using debris involve the addition of stable

debris to provide resting areas, overhead cover, and new pools for salmonids (Bisson et al. 1987). Sedell et al. (1985) predicted that salmon production in debris-impoverished streams could be increased by increasing the debris load. Hall and Baker (1982) also suggest that these measures would enhance existing wild stocks and maintain the genetic variability of these stocks. Moore and Gregory (1988) state "for stream enhancement projects to be successful, objectives must be identified and channel modifications must be designed to provide habitat characteristics appropriate for all stages of the early life history of stream fish".

The life history of the Clearwater River coho salmon has been extensively studied. Adults migrate up the river in late fall, spawning predominantly in small tributaries (Quinault Indian Nation and Washington Department of Fisheries, unpublished data). The eggs incubate in the gravel during the winter and hatch in early spring. Upon emerging, some fry may remain in the tributary to feed during the summer, while others migrate from the tributary and forage in the main stem. Beginning with the first fall freshets, juvenile coho salmon in small tributaries move further upstream, while main stem residents move predominantly downstream and into other small tributaries or riverine ponds to over-winter (Cederholm and Scarlett 1982). The juveniles then emigrate from the tributaries or ponds in the spring as smolts. The smolts migrate downstream to the ocean, where they live and feed for the next 1/2 to 1 1/2-years before returning mostly as 3-year-old adults.

Spawning habitat within the Clearwater River basin appears to be sufficient for large numbers of coho salmon spawners. There also appears to be adequate rearing area in the small tributaries. Wall-base channel habitats provide an important component of the winter ecology of juvenile coho salmon in the Clearwater River and have been the topic of earlier enhancement projects (Cederholm et al. 1988; Cederholm and Scarlett 1991). However, wall-base channel habitat also appears to be under-seeded (Peterson and Reid 1984). Significant numbers of coho salmon immigrants to wall-base channels originate from main stem summer rearing areas (Cederholm and Scarlett 1982). We believe that main stem summer rearing habitat may be one of the limiting factors to coho salmon production in the Clearwater system and that enhancement of that habitat could increase coho salmon recruitment into wall-base channels.

The specific objectives of this study were to 1) evaluate the effectiveness of introduced woody debris as summer rearing habitat for juvenile coho salmon, and 2) determine what physical characteristics of the debris piles may attract the most juvenile coho salmon and result in the largest contribution of coho salmon to wall-base channels.

Study Area

The study was conducted on the main stem Clearwater River and four of its riverine ponds (Figure 1). The Clearwater River originates on the west side of the Olympic Mountains. The headwaters begin approximately 58 river kilometers above its confluence with the Queets River (Winter and Wampler 1990). The river has a drainage area of over 350 km^2 (Cederholm and Scarlett 1982) which receives over 350 cm of rain annually (Cederholm and Scarlett 1991). The river is fed primarily by surface runoff and groundwater (Winter and Wampler 1990). Median discharge near the town of Clearwater for the years 1932 and 1938-1949, ranged from about 130 cfs to 330 cfs from June to September with a peak flood of 37,400 cfs recorded November 3, 1955 (Amerman and Orsborn 1987). The river gradient is low to moderate and is composed primarily of pool area with relatively short riffle sections. The study reach (enhanced reach) begins at two river ponds located approximately 16 km upstream from the Queets/Clearwater confluence and extends upstream to river kilometer 30.

The four riverine ponds monitored during the study include Coppermine Bottom Pond, Pond 2, Paradise Pond and Swamp Creek Beaded Channel. These ponds have been previously described (Peterson 1982a, Cederholm et al, 1988; Cederholm and Scarlett 1991). Paradise, Coppermine Bottom, and Pond 2 have surface areas of 0.5 ha, 0.85 ha, and 1.29 ha, respectively, and have outlet streams of approximately 350 m (Cederholm and Scarlett 1982). Swamp Creek Beaded Channel has a surface area of 0.27 ha and an outlet of approximately 220 m.

Material and Methods

The study design used in this work was divided into three parts: 1) the use of woody debris accumulations by juvenile coho salmon was determined using snorkel surveys and the numbers of coho salmon using natural and introduced accumulations were compared to controls; 2) physical variables were measured to classify the different debris stations; 3) juvenile coho salmon at each station type were differentially marked during low summer flow and examined for marks at the entrance to four wall-base channels downstream of the study reach during the fall. The number of coho salmon attracted by each station and the number of immigrants into wall-base channels, were used to determine which type of debris stations provided the best habitat.

Debris bundles were installed at predetermined enhancement sites by a ten-man crew traveling on foot along the river bank during early May. Two to three spruce (*Picea sitchensis*) or hemlock (*Tsuga heterophylla*) trees averaging 10-20 cm diameter at the butt end were removed from the adjacent riparian zone and manually carried to the edge of the river. At the river bank, the trees were laid parallel to each other and joined at their butt ends using either a rope or a large metal spike. The bundle of trees could then be easily rolled into the river and floated into the desired position. The bundles were then lashed to an existing tree or rock so the submerged end was in contact with the substrate. Ideally, we wanted the debris bundle to be located at a depth of one meter or more during low summer flow, with the outer edge projecting into the current to create a back eddy.

Stations were surveyed by snorkelers to determine coho salmon abundance during low summer flow. The three station habitat types were enhanced (debris added), natural (natural debris only), and controls (no debris). Two snorkelers entered the river upstream from the area to be surveyed and proceeded downstream, counting the coho as they moved past the debris station. Once well past the debris station, the snorkelers moved upstream past the debris station to make a second estimate. The two snorkelers' then discussed their individual estimates and came to a consensus, which was the estimate of coho salmon abundance at the station. This procedure was followed at each station. Each station was snorkeled twice once in mid-August and again in mid-September.

The introduced and natural debris stations were classified by their physical variables.

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The variables measured included water depth and velocity, light aspect (exposure), riverine habitat type, cover area, tree species, and debris density. All measurements were taken after the area had been snorkeled. Water depth was measured using a surveyors' pole and was measured to the nearest tenth (0.1) of a foot. Depth was measured at two locations, the outer edge of the debris station and half way from the shore to the outer edge of the station (Figure 2). Current velocity was measured to the nearest tenth of a foot per second at these same locations using a Marsh-McBirney model 201 current meter. All velocity measurements were taken approximately at mid-depth. Additional velocity measurements were taken in the center and at the upstream edge of the debris station (Figure 2). Debris length and average width were also measured using a surveyors pole. The length of the debris was taken as the maximum distance the debris extended downstream and the width was the estimated average distance the debris extended from the bank towards the center of the river. The exposure of the debris station was determined using a compass on a line perpendicular to the bank. Riverine habitat was designated as pool, riffle, or glide as defined by Bisson et al. 1982. Debris density was determined visually by the structural complexity of the debris. Debris structures which were very complex were classified as dense, while those with little complexity were classified as sparse. Debris stations classified as medium were debris areas with a mixture of the two above classifications.

Juvenile coho salmon captured at debris stations were marked with a freeze brand specific to each debris station. Juvenile coho were freeze branded between 10 September and 19 September, 1990. Due to the large number of stations, long stretches of river, and time constraints, we attempted to capture coho salmon for freeze branding only at stations having an estimated population of 50 or more juvenile coho salmon. Juvenile coho salmon were captured using beach seines or purse seines. Captured coho salmon were anesthetized with MS-222 (tricane methanesufonate). They were then measured, weighed, and freeze branded (Bryant and Walkotten 1980) and put into a recovery container. Once fully recovered, the fish were released into the debris station from which they were captured.

Coho salmon were subsequently captured and checked for brands as they migrated into four different wall-base channels. Two-way live box traps were operated on outlets of the four wall-base channels from 8 October until 30 December, 1990. (The traps on

Coppermine Bottom and Pond 2 were not installed until October 22, 1990, due to permit requirements.) The traps were checked every other day (every day during high precipitation periods). The fish were removed from the live boxes, anesthetized, checked for brands, and a sub sample of 25 were weighed and measured. Upon recovery, the fish were released on the side of the trap toward which they were migrating (generally upstream).

Estimates of juvenile coho salmon abundance were skewed and were therefore transformed using a square root transformation $(X'=SQRT(X=0.5))$ (Zar 1984). This transformation normalized the data (before: skewness=2.15; after: skewness=1.33) and reduced variability.

Coho salmon abundance at each station type (enhanced, natural, control) was compared using a one-way-analysis-of-variance (ANOVA). Least square means (LS means) procedures were used to determine which set of means were significantly different $(P<0.05)$ if the ANOVA revealed a significant difference $(P<0.05)$. This procedure was also employed to determine if measured categorical variables (data which fits into categories, e.g., density=dense, medium, sparse) significantly affected juvenile coho salmon abundance at the stations. Linear regression was used to evaluate the effects of measured continuous variables (e.g., depth=0-3 m) on coho salmon abundance at the different stations. Multiple regression also was employed to build a statistical model to identify those variables important for providing coho salmon habitat. The data was analyzed singly (introduced debris data only, natural debris data only) and combined.

Results

A total of 90 study stations were evaluated during the 1990 field season. Of the 90, 48 were introduced debris, 38 were natural debris, and 4 were control stations. During snorkel surveys, a total of 3,835 juvenile coho salmon were estimated to be using all debris stations studied. Other species noted were steelhead (*Oncorhynchus mykiss*), cutthroat trout (*O. clarki clarki*), chinook salmon (*O. tshawytscha*), speckled dace (*Rhinichthys osculus*), prickly sculpin (*Cottus asper*), and mountain whitefish (*Prosopium williamsoni*).

The mean number of coho salmon fry residing at the three different types of debris

stations was significantly different during both August ($F=5.36$, $P=0.0064$) and September ($F=5.68$, $P=0.0049$). Both natural and introduced debris areas had significantly more coho salmon fry than did control stations, while no difference was observed between natural and introduced debris areas (Table 1).

Of the class variables tested (debris density, riverine habitat, bank, substrate, debris species, exposure), debris density was the only one to significantly affect coho salmon abundance (Table 2). When data from both introduced and natural debris were combined LS means revealed that significantly more coho salmon were present in dense debris areas than in either medium or sparse debris areas during both August and September (Table 2, Figure 3). For the introduced debris, there were significantly more coho salmon at the dense than at sparse stations in August. In contrast, significantly more coho salmon were observed in dense debris than both medium and sparse accumulations in September (Table 2, Figure 3). In natural debris accumulations, significantly more coho salmon were observed in dense stations than in either medium or sparse accumulations in August. However, no significant differences were observed in September.

Of the continuous variables (front current, outer current, back current, center current, mid-depth, outer depth, and surface area), only surface area of the debris station significantly affected coho salmon abundance in combined and individual analysis of introduced and natural debris stations (Table 3). Coho salmon abundance tended to increase as the surface area of the debris increased (Figure 4). The depth on the debris station outer edge was nearly significant on two occasions, however the variable explained very little of the variability (combined analysis for September snorkel surveys, $F=3.69$, $P=0.0583$, $r=0.0452$; natural debris analysis for September snorkel surveys, $F=3.06$, $P=0.0898$, $r=0.0873$).

Debris surface area was the only variable to significantly affect the difference in coho salmon abundance between the August and September snorkel surveys. A significant difference was observed in the combined analysis ($F=4.08$, $P=0.0498$, $r=0.0498$). There was an inverse relationship toward a reduction in coho salmon abundance as surface area increased (Figure 5). However, no significant difference was observed in the introduced

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(F=3.44, P=0.0705, r=0.0724) or natural debris analysis (F=0.53, P=0.4717, r=0.0163). The current in the center of the debris station was nearly significant for natural debris stations (F=3.59, P=0.0679, r=0.1068).

Multiple regression models were developed for the combined and individual analysis of introduced and natural debris using both the August and September data (Table 4). The models for the combined analysis in September and the natural debris only analysis for August and September were identical (Table 4). The models for the combined analysis for August had one more term than the above models, this being an interactive term between debris surface area and debris density. Debris surface area and debris density were significant variables in all models. Riverine habitat was a significant term in all models, except those for the introduced debris and the combined analysis in September. However, it was included in the combined analysis for September because the debris surface area/riverine habitat interactive term was statistically significant.

The models for the introduced debris stations were somewhat different than the best models for the combined analysis and the natural debris analysis (Table 4). The current velocity in the center (or in front) of the debris station and the depth on the outer edge of the debris station were significant variables. The current in front of the debris station could be substituted for the current in the center of the debris without severely compromising the results (Table 4). Since these two variables were highly correlated, no models with both variables were tested. Unlike the combined or natural debris test, neither riverine habitat nor the interaction between riverine habitat and debris surface area were statistically significant variables.

Debris surface area exhibited a significant relationship with riverine habitat type for the combined analysis and the natural debris only analysis in August and September (Figures 6 and 7). Increasing debris surface area in pools had a greater affect on coho salmon abundance than increasing debris area in glides or riffles for the combined analysis in August and September (Figure 6). In contrast, increasing debris surface area had a positive effect on coho salmon abundance in pools and riffles for the natural debris analysis in August and September although, increasing debris surface area in glides did not affect coho salmon abundance (Figure 7). A significant relationship between debris surface area and debris

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density was also observed for the combined analysis in August (Figure 8). Increasing debris surface area of dense debris structures had positive influence on coho salmon abundance, while no significant effects were observed in medium and sparse structures (Figure 8).

A total of 909 juvenile coho salmon were branded from natural and introduced debris stations between 10 September and 19 September, 1990. Of these, 680 were from 10 introduced debris stations, and 229 were from 2 natural debris stations.

Twenty-one branded fish were captured as they migrated into four wall-base channels between 4 October, 1990 and 8 January, 1991 in Paradise and Swamp Creek Beaded Channel and between 22 October and 27 December in Pond 2 and Coppermine Bottom Ponds (Table 5). However, the traps were inundated for 5 days in November which prevented sampling during that period. Coho salmon likely moved into the ponds during high water events, causing lower than expected immigrations and brand retrievals.

Natural debris stations provided more (14 to 7) and a higher percentage (natural, 14/229=6.11%; introduced, 7/680=1.03%) of wall-base channel immigrants than introduced debris stations. Eight of the 12 different types of brands used were retrieved, with 6 of 10 brands from introduced debris stations recovered, while both natural debris stations' brands were recovered. The distance between the release station and the first downstream pond was greater for introduced debris stations (mean=4.2 km, SD=2.6) than natural debris stations (mean=1.0, SD=1.0), however this difference was not significant (t-test, $P>0.05$). No significant differnce existed in the average distance traveled by recaptured coho salmon (introduced, mean=6.86, SD=4.79; natural, mean=6.29, SD=5.08; t=0.25, $P>0.05$).

Discussion

The presence of woody debris appears to be an important variable influencing utilization of the main stem Clearwater River by Coho salmon. No coho salmon were observed in four control pools without woody debris. Coho salmon abundance also increased as debris density increased and was positively correlated with debris surface area. Our results support the findings of other investigators regarding the importance of woody debris habitat to juvenile coho salmon in small streams (Bustard and Narver 1975a; Bisson et al. 1982; Bryant 1982; Dolloff 1986; Shirvell 1990). Coho salmon fry were found in areas

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previously used infrequently before artificial rootwads were placed there (Shirvell 1990). Woody debris habitat has also been shown to be important to coho salmon in small streams during the winter (Bustard and Narver 1975b). Also, stream sections cleared of woody debris supported fewer coho salmon than sections with woody debris (Bryant 1982; Dolloff 1986).

Historic evaluation of river conditions reveals that large rivers (up to 7th order) contained large amounts of woody debris and were often obstructed by jams up to 1,500 m long (Sedell and Luchessa 1982). In contrast, we observed only 38 natural debris accumulations over a 14-km stretch of main stem river. Many of these accumulations were single alders while others were larger debris accumulations (up to 150 m^2). We were able to introduce an additional 48 enhancement structures in this same stretch of river and many more structures could have been introduced. We believe that these enhancement structures could increase the summer rearing capacity, thereby reducing a limiting factor to coho salmon production in the Clearwater River Basin. Coho utilization of enhanced and natural reaches within the Clearwater River will be evaluated in subsequent years.

No other measured environmental variable significantly influenced coho salmon abundance when tested singly. This is contrary to the results of other investigators on habitat requirements of juvenile coho salmon (Murphy et al. 1989; Nickelson et al. 1992a). Murphy et al. (1989) observed the highest densities of coho salmon in still or slow water (< 10 cm/s). We observed no significant difference in coho salmon abundance in current velocities ranging from 0 to 116 cm/s. However, 9 of the 10 highest counts were observed in stations with current velocities below 15 cm/s. Riverine habitat type also did not significantly influence coho salmon abundance at the debris stations. In small streams, coho salmon are most abundant in pools throughout the year (Nickelson et al. 1992a).

Our final evaluation of success of introduced debris bundles was the number of immigrants they contributed to wall-base channels. Wall-base channels are important over-wintering areas contributing between 25-65 percent of the annual smolt production of the Clearwater River (Dave King, 1992, Washington State Department of Fisheries, personal communication). A majority of the coho overwintering in wall-base channels originate from summer rearing areas within the main stem (Cederholm and Scarlett 1982). Wall-base

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channels can apparently support more coho salmon than currently use these habitats (Peterson and Reid 1984). Natural debris structures provided greater numbers and much higher percentages of wall-base channel immigrants than introduced debris stations. Perhaps our results were influenced by the fact that we branded and released coho salmon from only two natural debris stations. This may have provided a biased representation of the contribution of natural debris structures to wall-base channels. Our recovery rate of coho salmon branded in main stem study sites was lower than that reported in other studies on the Clearwater River (Cederholm and Scarlett 1982). Year-to-year variability may have resulted in our low recovery rate.

A total of 1625 and 1240 coho salmon were estimated to be using all the introduced and natural debris stations during the September survey, respectively. Using the brand recovery rates, which would result in a conservative estimate, we calculated the total contribution of all debris stations to wall-base channel immigration at the four wall-base channels we monitored to be 21 and 76 coho salmon from introduced and natural debris stations, respectively. The Quinault Indian Nation also monitors four additional ponds downstream from our study reach, which have nearly the same average annual smolt production as the ponds we monitored (Quinault Fisheries Division 1992). Thus, an additional 21 and 76 coho salmon would be estimated to move into these ponds during the fall from introduced and natural debris stations, respectively. It is possible that coho salmon may have moved into other wall-base channels or small free-running tributaries below our enhanced reach. Thus, it is likely that our enhancement structures could contribute slight increases in coho salmon immigration into wall-base channels below our enhanced reach. One must remember that our enhancement project covers only a small portion of the main stem (14 of approximatley 50 km). This calculation also only takes into account eight wall-base channels. In an ongoing study, the Washington Department of Fisheries has described more than 30 such habitats in the Clearwater River Basin (Dave King, 1992, Washington Department of Fisheries, personal communication). Thus, there is the possibility that enhancement of the entire main stem could contribute to significant increases in coho salmon immigration into wall-base channels.

Conclusions

Preliminary results suggest that introduced woody debris is at least as effective as natural debris stations in attracting and sustaining juvenile coho salmon during the summer. The most effective debris structures appear to be large, dense structures in pools. However, there is some indication that introduced structures provide fewer wall-base channel immigrants than naturally occurring debris. Preliminary results suggest that this technique could be used to increase the summer rearing capacity of the main stem Clearwater River.

Acknowledgements

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Table 1.   Mean (Standard Deviation) coho abundance at the different debris stations for August and September, 1990.

	Mean Density	
	August	September
Natural debris	45.8 (51.5)	36.5 (44.8)
Introduced debris	43.7 (52.9)	35.3 (36.4)
Control (no debris)	0	0

Table 2.   Relationship between coho abundance and debris density at
natural and introduced debris stations (combined and individual
analysis).

Comparison	F	P	LS means comparison	P
		Combined		
August	9.66	0.0002	Dense X Medium	0.0094
			Dense X Sparse	0.0001
			Medium X Sparse	0.0617
September	6.83	0.0019	Dense X Medium	0.0019
			Dense X Sparse	0.0095
			Medium X Sparse	0.7960
		Introduced		
August	4.31	0.0198	Dense X Medium	0.1093
			Dense X Sparse	0.0061
			Medium X Sparse	0.1097
September	5.43	0.0082	Dense X Medium	0.0029
			Dense X Sparse	0.0452
			Medium X Sparse	0.7698
		Natural		
August	5.88	0.0063	Dense X Medium	0.0230
			Dense X Sparse	0.0069
			Medium X Sparse	0.5116
September	2.28	0.1194	Dense X Medium	0.2129
			Dense X Sparse	0.0640
			Medium X Sparse	0.4389

Table 3.   Results of linear regression with the independent variable debris surface
               area and the dependent variable coho abundance.

Comparison	Month	F	P	r
Combined	August	25.03	0.0001	0.2296
Combined	September	19.10	0.0001	0.1967
Introduced	August	17.09	0.0001	0.2709
Introduced	September	12.37	0.0010	0.2195
Natural	August	7.70	0.0087	0.1762
Natural	September	6.45	0.0162	0.1678

Table 4.   Type III Sums of Squares (SS), significance level and correlation coefficients
               for the best fit multiple regression models of coho abundance with physical
               variables of natural and introduced debris (combined and individual analysis).

Date	Type III SS Significance					P	r
Combined Introduced and Natural Debris							
Model terms:	area	density	habitat	area*density	area*habitat		
August	0.0027	0.0259	0.0583	0.1110	0.0280	0.0001	0.4714
Model terms:	area	density		habitat	area*habitat		
September	0.0012	0.0200		0.4237	0.0436	0.0001	0.3796
Natural Debris							
Model terms:	area	density		habitat	area*habitat		
August	0.0076	0.0076		0.0062	0.0003	0.0001	0.6592
September	0.0201	0.0470		0.0023	0.0009	0.0004	0.6097
Introduced Debris							
Model terms:	area	density		current center	depth outer		
August	0.0001	0.0047		0.0022	0.0153	0.0001	0.5417
September	0.0001	0.0007		0.0015	0.0716	0.0001	0.5698
Model terms:	area	denstiy		current front	depth outer		
August	0.0001	0.0114		0.0091	0.0351	0.0001	0.5058
September	0.0015	0.0038		0.0845	0.2733	0.0005	0.4676

Table 5.   Number of juvenile coho, branded and unbranded, counted migrating
                into four wall-base channels of the Clearwater River.

Pond	Sampling Period	Total Coho	Brands
Coppermine Bottom	10/22-12/27	1428	7
Pond 2	10/22-12/27	531	4
Swamp Creek Beaded Channel	10/4-1/8/91	1479	2
Paradise Pond	10/4-1/8/91	1835	8
Total		5002	21
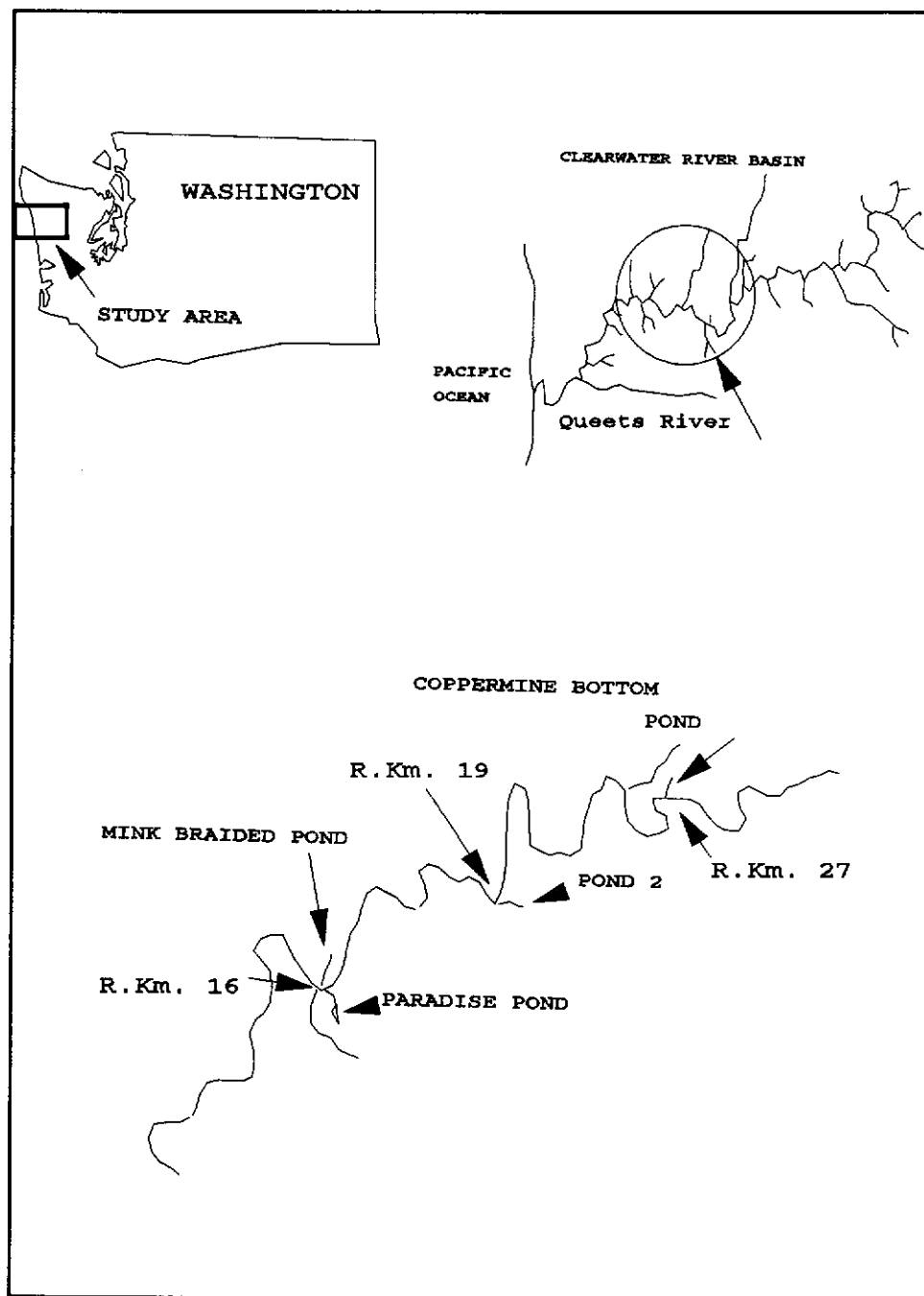
Figure 1.   Location of the study area on the Clearwater River, Washington
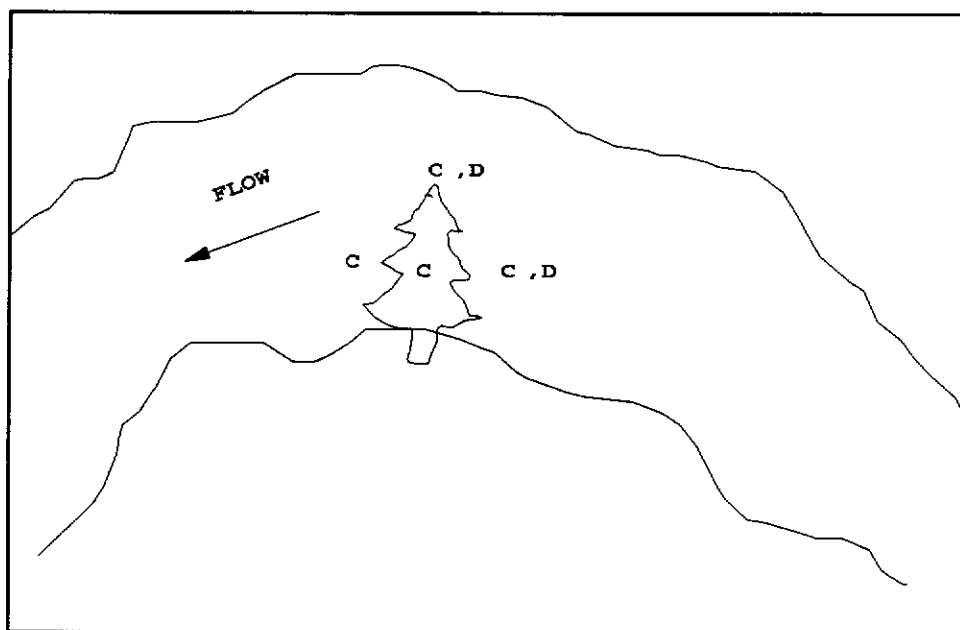
Figure 2. Location of physical parameter measurements.
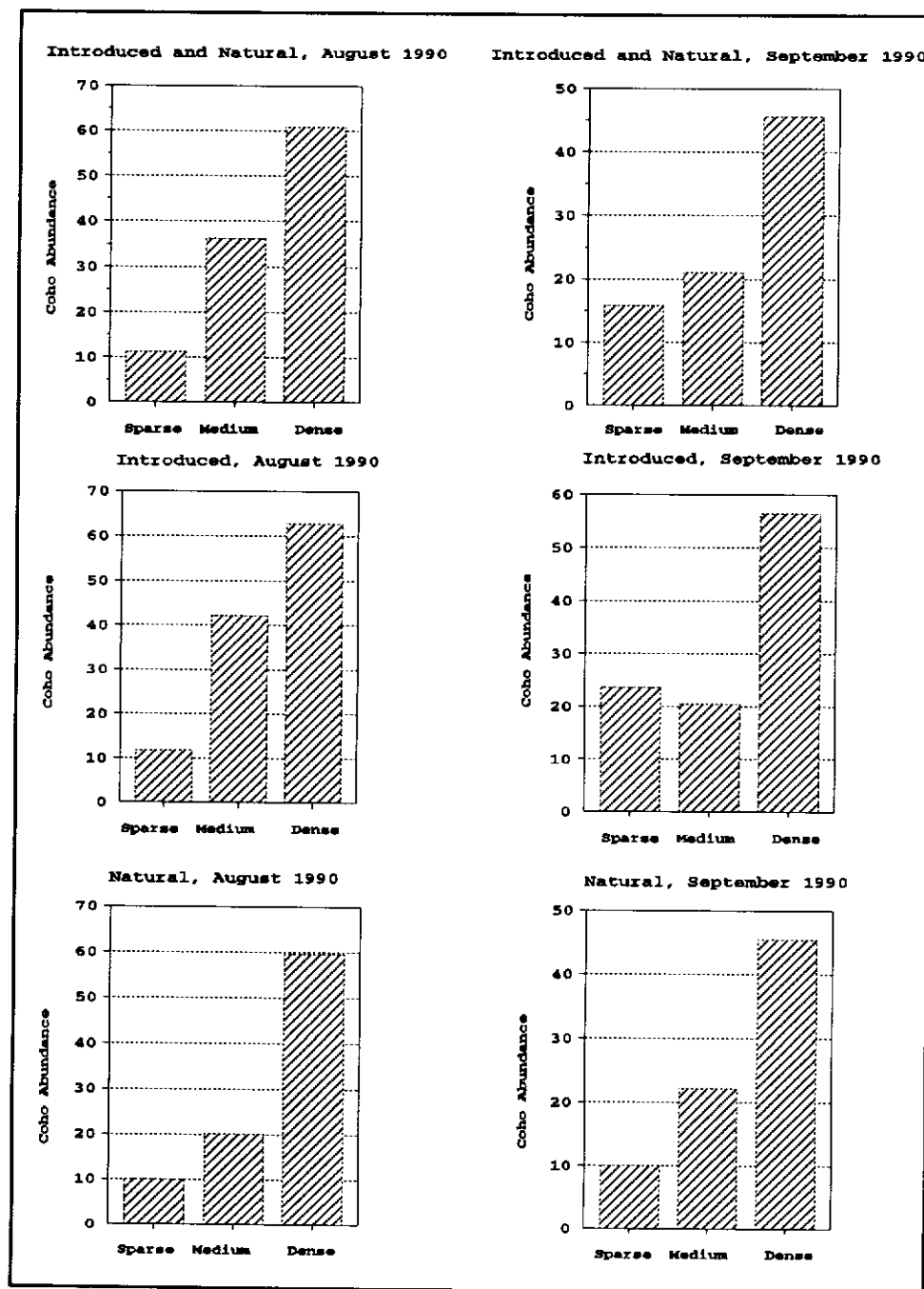
Figure 3.   Coho abundance at sparse, medium, and dense debris at introduced and

natural debris stations in August and September, 1990 (combined and
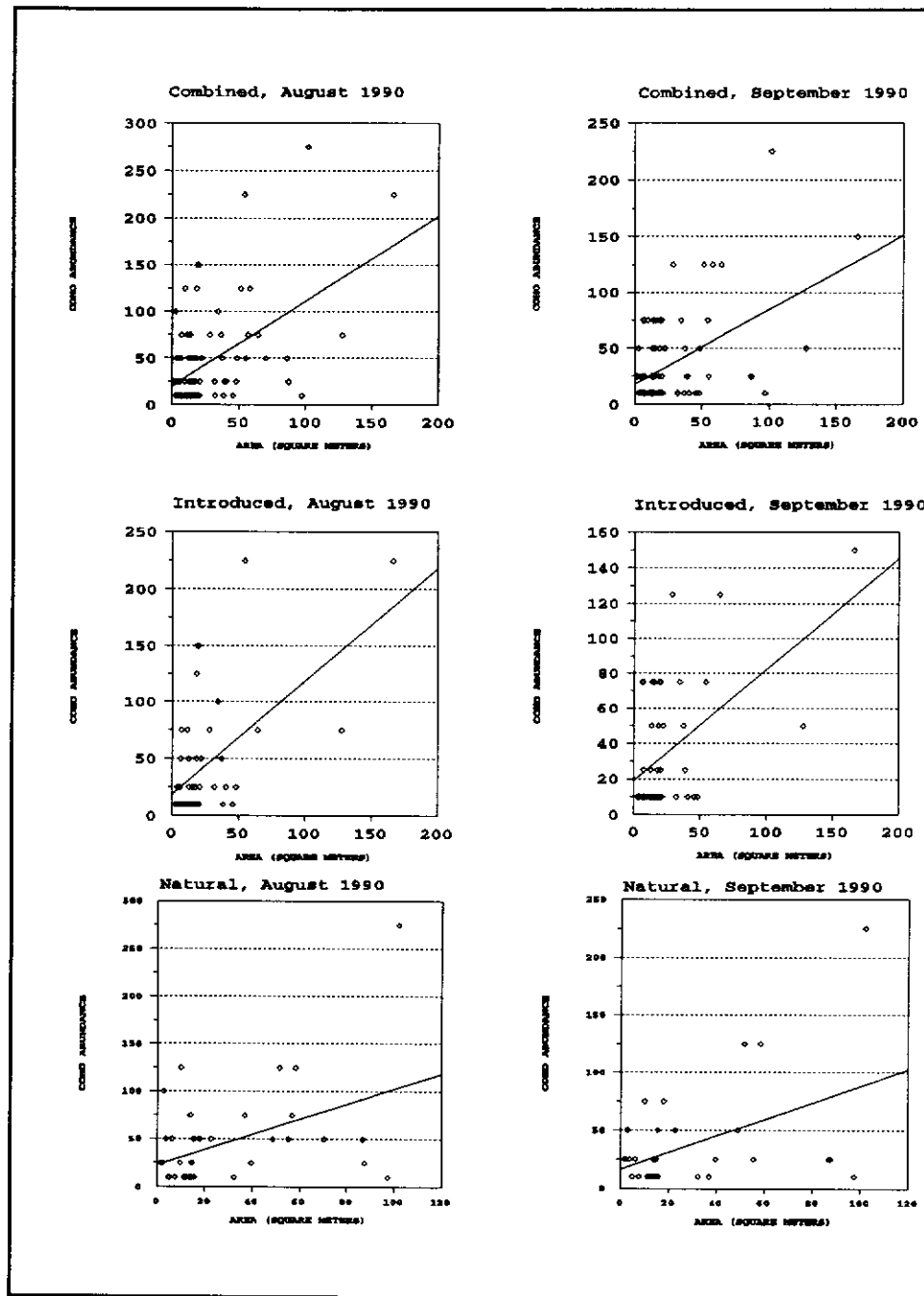
individual analysis)

Figure 4.   Regression lines coho abunance against debris surface area for

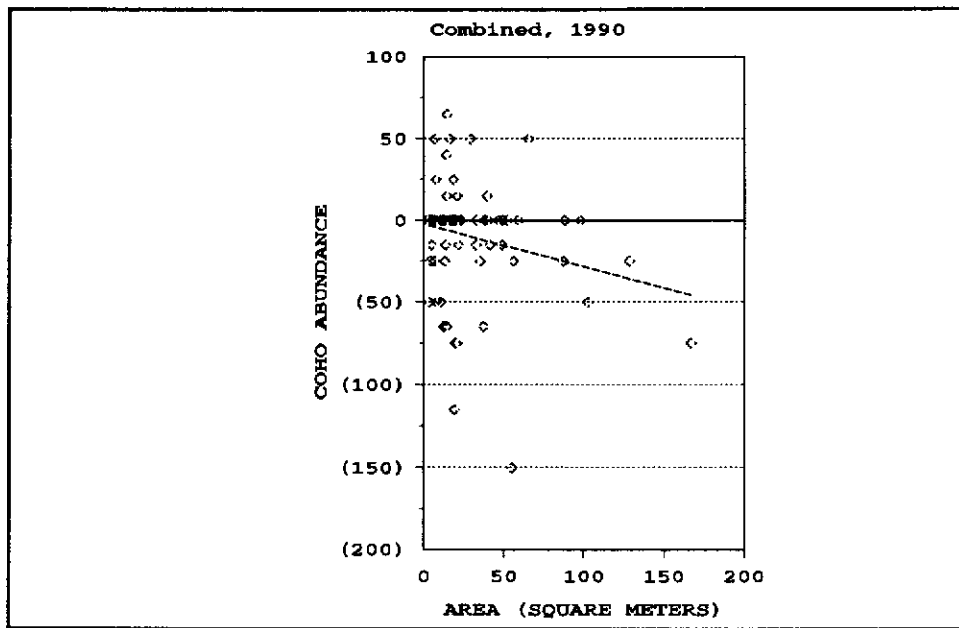the combined and individual analysis of natural and introduced

debris.

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Figure 5.   Regression line of the difference in coho abundance between

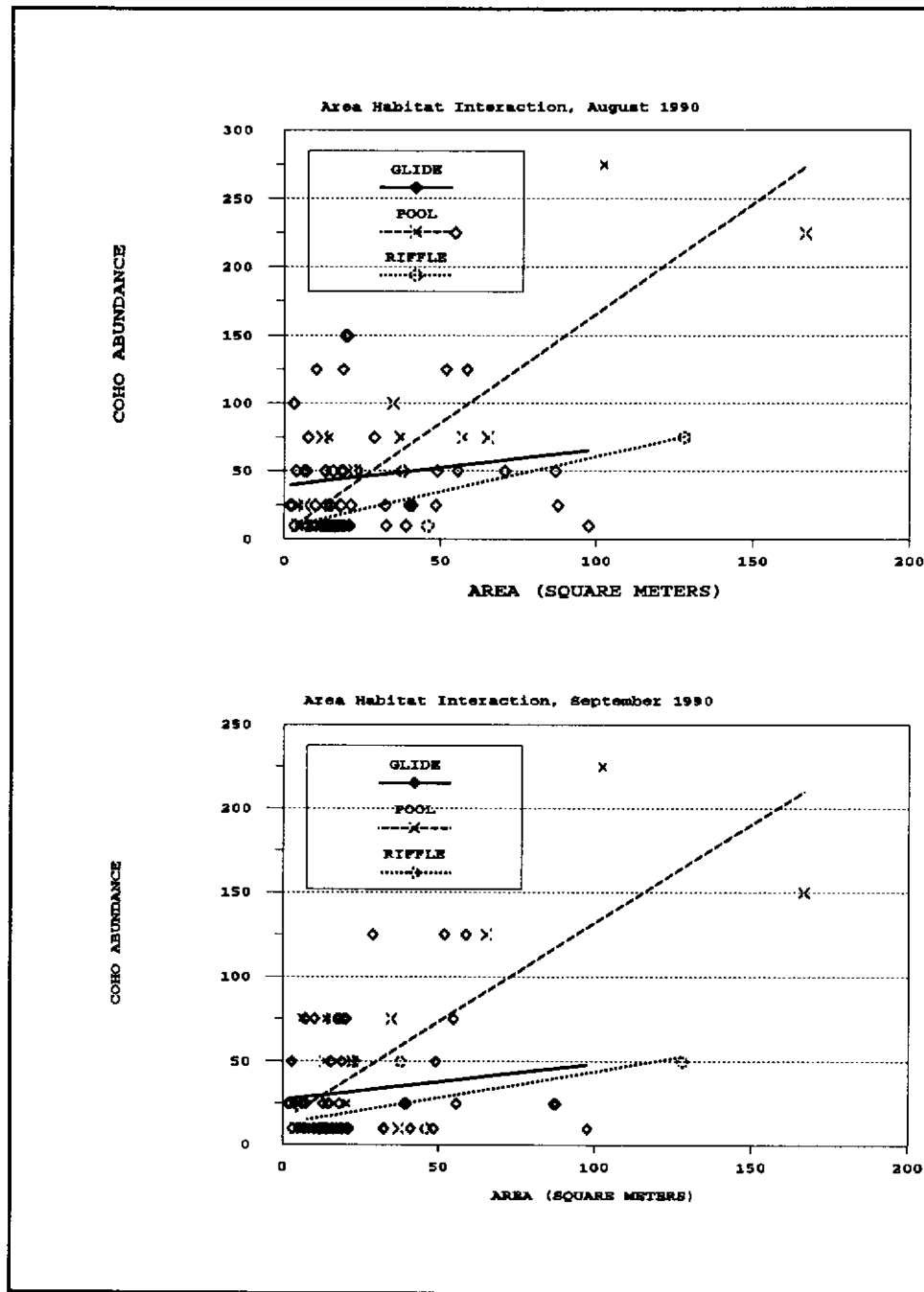August and September snorkel surveys and debris surface area.

Figure 6.   Relationship between surface area of debris and riverine habitat for the combined introduced and natural debris analysis using the August and September surveys.
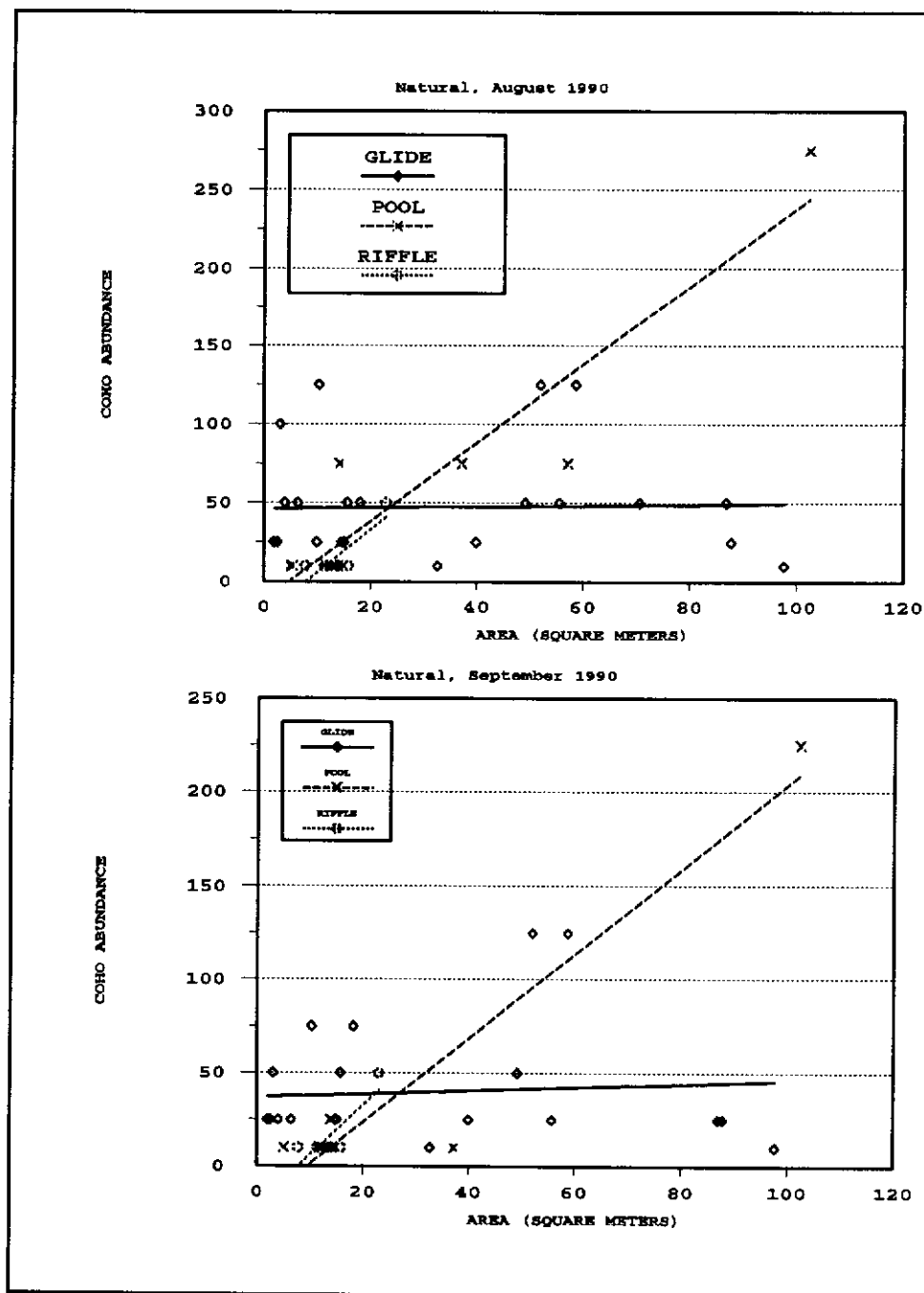
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Figure 7.   Interaction between surface area and riverine habitat type for

natural debris analysis using both the August and September snorkel

survey.

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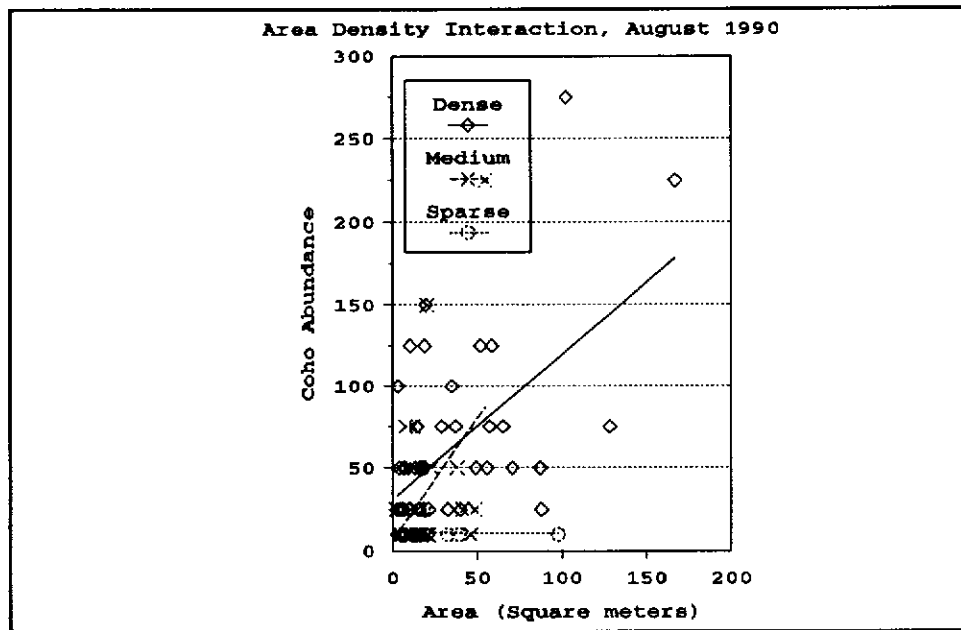**Area Density Interaction, August 1990**

Figure 8.   Interaction between surface area and density of debris for

the combined introduced and natural debris data analysis using

the August snorkeling data.